On the Susceptibility of Cold Tropical Cirrus to Ice Nuclei Abundance

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Numerical simulations of cirrus formation in the tropical tropopause layer (TTL) are used to evaluate the impact heterogeneous ice nuclei (IN) abundance on cold cloud microphysical properties. The model includes homogeneous and heterogeneous ice nucleation, deposition growth/sublimation, and sedimentation. Reanalysis temperature and wind fields are used to force the simulations, with addition of high-frequency wave temperature variability based on in situ measurements. The model results are constrained by recent in situ observations of TTL cirrus and relative humidity, as well as satellite measurements of cirrus bulk properties and occurrence frequencies. Temperature variability driven by high-frequency waves has a dominant influence on TTL cirrus microphysical properties and occurrence frequencies, and inclusion of these waves is required to produce agreement between the simulated and observed cloud properties as well as the abundance of TTL cirrus. With a composition-independent supersaturation threshold for homogeneous freezing of aqueous aerosols, the model produces excessive ice concentrations compared with in situ observations. Inclusion of relatively numerous heterogeneous nuclei (> 100/L) in the simulations improves the agreement with observed ice concentrations. However, when IN contribute significantly to TTL cirrus ice nucleation, the occurrence frequency of large supersaturations with respect to ice is less than indicated by in situ measurements. The simulated TTL cirrus extinction statistics agree with observations (within uncertainties) from both in situ and remote-sensing measurements. We find that the sensitivity of TTL cirrus extinction and ice water content statistics to heterogeneous ice nuclei abundance is relatively weak. Likewise, the simulated occurrence frequencies of TTL cirrus are insensitive to ice nuclei abundance, both in terms of cloud frequency height distribution and regional distribution throughout the tropics.